Radiation Physics Note 49

TESTING OF A LARGE AREA PLASTIC SCINTILLATOR AS A POSSIBLE GATE MONITOR

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The response of a large-area radioactivity monitor to radioactive sources transported on automobiles was studied as a function of vehicle speed and source activity. The device, NE8470, is manufactured by Nuclear Enterprises Limited,[1] and is intended to be used at accelerator laboratories and nuclear reactor installations to reduce the risk of activated material being removed from a controlled area without proper precautions. Its possible use at Fermilab would be as a gate monitor to detect unauthorized transport of radioactive material away from the site.

The monitor consists of an 122 cm by 46 cm slab of NE110 plastic scintillator, 5.1 cm thick, covered by thin aluminum sheets, supported by a welded aluminum-alloy frame, and viewed by a single 5.1 cm diameter photomultiplier tube. The signals from the phototube are shaped, amplified and fed to two window discriminators, whose output can be sent to an external ratemeter and recording device. At the same time circuitry is incorporated to allow for background detection and its subtraction from total counts over a user-set sampling time between 0.25 and 2 sec. A digital comparator generates an alarm signal in each sampling period during which the background level is exceeded by a fixed user-set amount.

For the present tests, the monitor was set-up at the Wilson Road guardhouse. It was placed a distance of about 3 m. from the center of the outgoing traffic lane. ^{60}Co radioactive sources of 5 to 118-μCi, a ^{22}Na source of 20-μCi activity, and two ^{137}Cs sources of 19- and 201-μCi were transported at speeds up to 60 mph through the gate. The response of the monitor at a sampling time of 0.25 sec. was observed with the threshold-level set to a value of 0.9 μR/hr above the average background level (typically about 12 μR/hr at Fermilab).

The results are shown in Fig. 1. The minimum activity detected by the the monitor at a given vehicle velocity is plotted as a function of velocity. The dashed curve represents the approximate response to ^{137}Cs gamma rays, and was generated by multiplying the ^{60}Co results by the ratio of the Cs to Co responses at velocities at and below 5 mph. The difference in monitor sensitivity between ^{137}Cs and ^{60}Co of a factor of $\sim$2.7 agrees with Fig. II in Ref.[2]

Fig. 2 shows the minimum detectable ^{60}Co activity as a function of perpendicular source-to-detector distance, for various vehicle velocities, obtained from Fig. 1 using the known[2] dependence of monitor sensitivity on distance. At 1 m., for example, a 25-μCi ^{60}Co source would be detected even if the vehicle were traveling at $\sim$60 mph. This activity corresponds to a dose-rate at 1 foot of $\sim$0.35 mR/hr for zero velocity. 25-μCi is also the minimum activity detected at a more realistic (unrestricted) exit speed of 45 mph and source-to-monitor distance of 2 m. For ^{137}Cs γ-rays, which are more representative of the energy of radioactivated items that might be transported away from Fermilab, the minimum detectable activity is $\sim$67-μCi under the same conditions.[3] This, however, results in a dose-rate of only $\sim$0.2 mR/hr at 1 foot.

According to the Code of Federal Regulations,[4] any person possessing 10 μCi or less of ^{137}Cs is exempt from the requirements of a license. On the basis of the present results such an activity could be detected in a vehicle traveling at speeds of 30-35 mph if the distance to the monitor was 1 m. or less.

At Los Alamos National Laboratory a gate monitor system based on a 5" diameter by 2" thick NaI detector is in use.[5] Fig. 3 shows the ratio of the efficiency for the NE110 plastic in the NE8470 monitor to that for such a NaI detector for 0.5 MeV γ-rays. The calculation is based on a simplified version of the expression given by Heath[6] for the efficiency of a cylindrical detector[7] for a point-source of radiation. In spite of the larger NaI intrinsic efficiency, the solid angle associated with the large area of the plastic makes the overall efficiency of the NE8470 at least an order of magnitude greater than that for the NaI detector over distances from ∿20 cm to 3 m. or more. Note, however, that higher background counting rates in the larger area detector detract somewhat from the advantages of this enhanced efficiency.

We thank Rich Allen for his help in the initial stages of these tests.

REFERENCES

1. We thank Barry Wilson of Nuclear Enterprises America for the loan of the instrument for evaluation.

2. Instruction Book: NE8470, Radioactivity Monitor, Nuclear Enterprises, Ltd.

3. Obtained from Fig. 2 for ^{60}Co by multiplication by the factor 2.7 as discussed in the text.

4. Code of Federal Regulations, CFR 10, Ch. 1, part 30.71 (Revised 1/1/83).

5. Jerry Miller, Private Communication (1984).

6. Heath, R. L. August 1964. Scintillation Spectrometry Gamma-Ray Spectrum Catalogue. IDO 16880-1, 2nd Ed.

7. The rectangular-shaped NE110 plastic was replaced by a cylindrical slab with the same area.

FIGURE CAPTIONS

1. Minimum detectable activity as a function of velocity for ^{60}Co, ^{137}Cs and ^{22}Na sources at a source-to-monitor distance of 3 m. The points at 60 mph should be considered only as upper limits. The solid curve represents the response to ^{60}Co and the dashed curve the approximate response to ^{137}Cs as discussed in the text.

2. Minimum detectable activity as a function of perpendicular source-to-monitor distance, at various speeds for ^{60}Co sources. To obtain approximate ^{137}Cs responses multiply these numbers by 2.7 as discussed in text.

3. Ratio of the total efficiency of the 122 cm by 46 cm by 5.1 cm thick plastic scintillator to that for a 12.7 cm diameter by 5.1 cm thick NaI detector as a function of source-to-detector distance for 0.5 MeV γ-rays.

FIG. 1 Minimum Activity as a function of Vehicle Velocity that will be Detected at a ⊥ Distance of ≈3m.

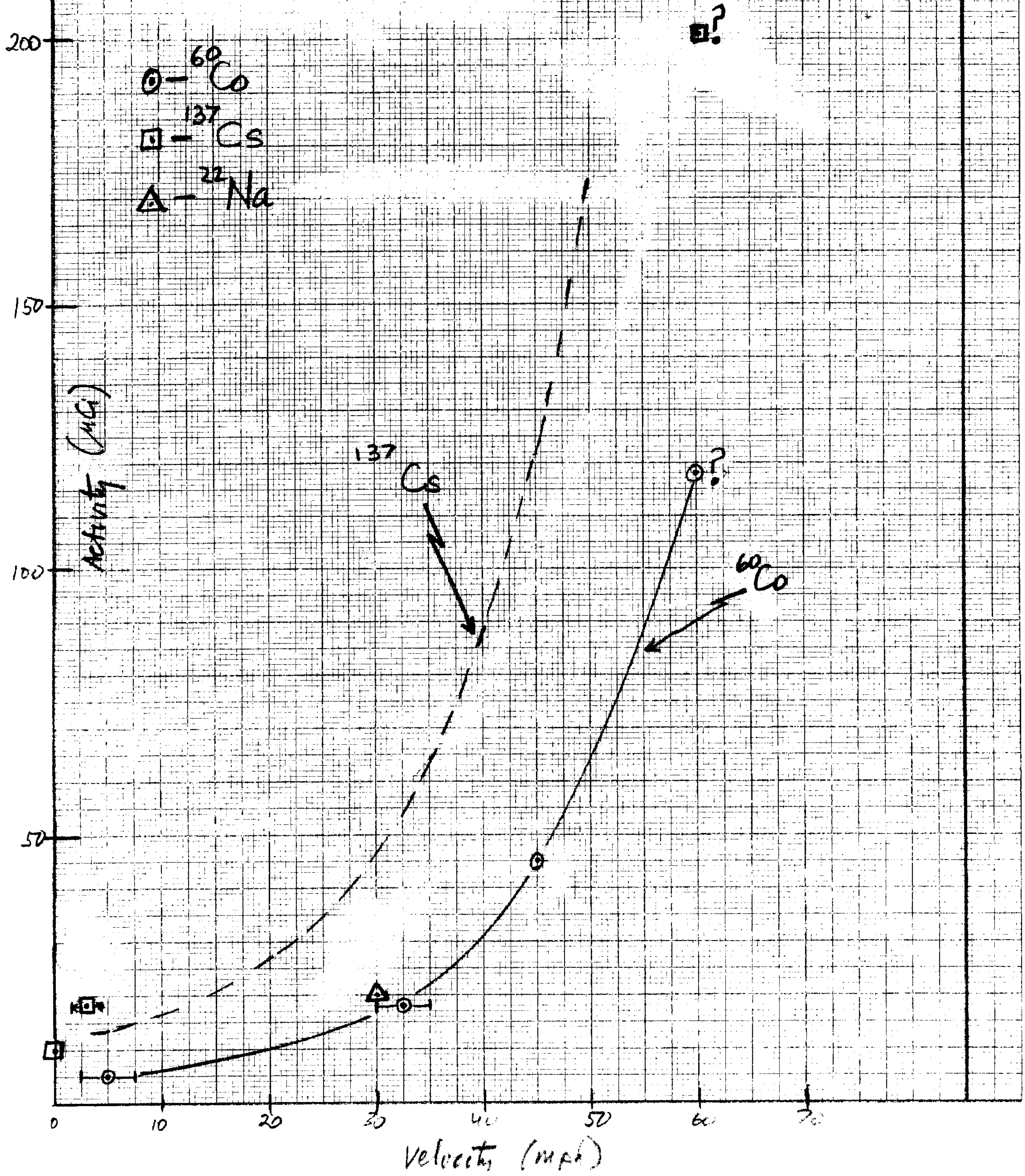

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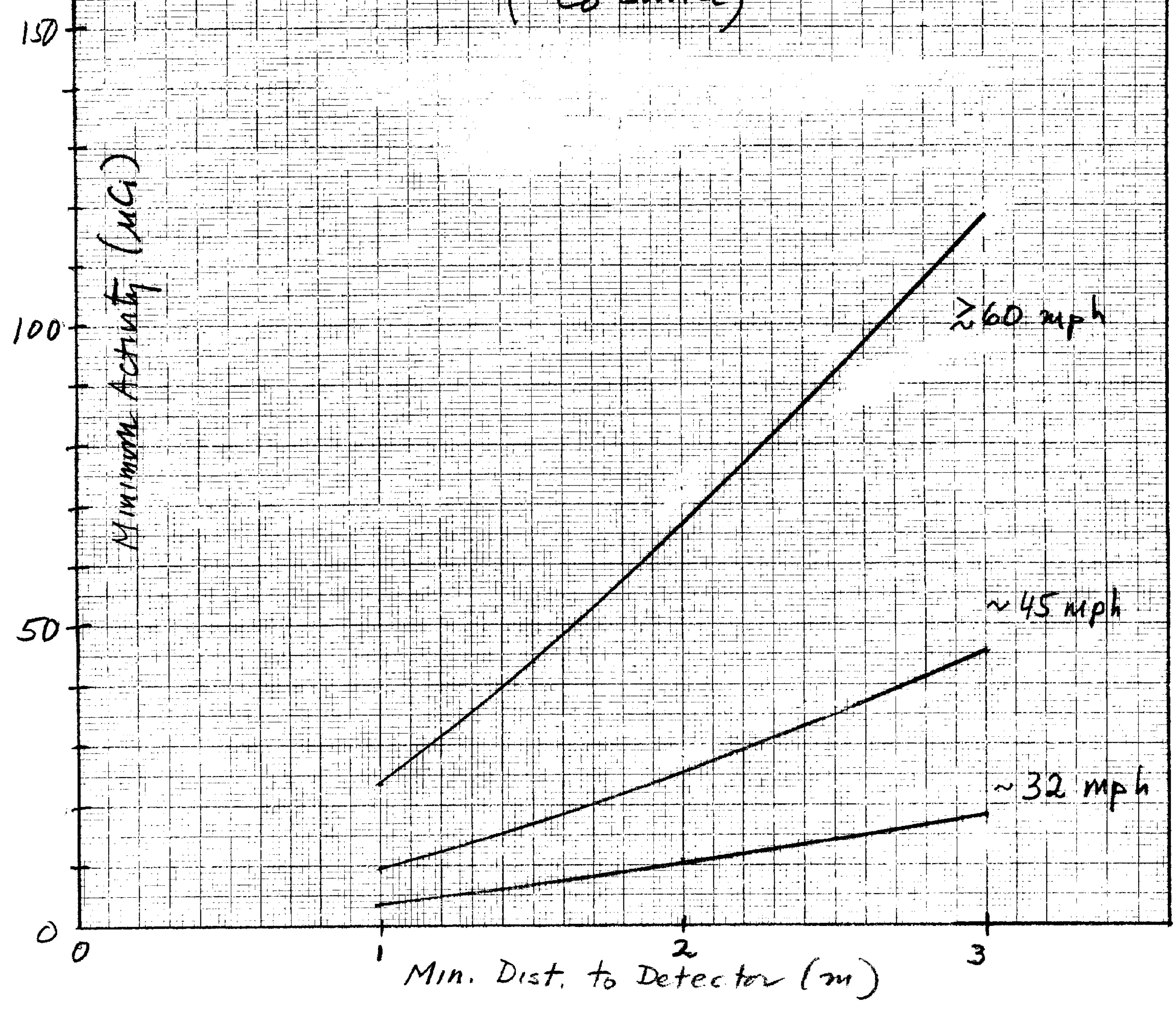
FIG. 2

Minimum Activity as Function of ⊥ Distance to Detector for various Vehicle Speeds

(^{60}Co source)



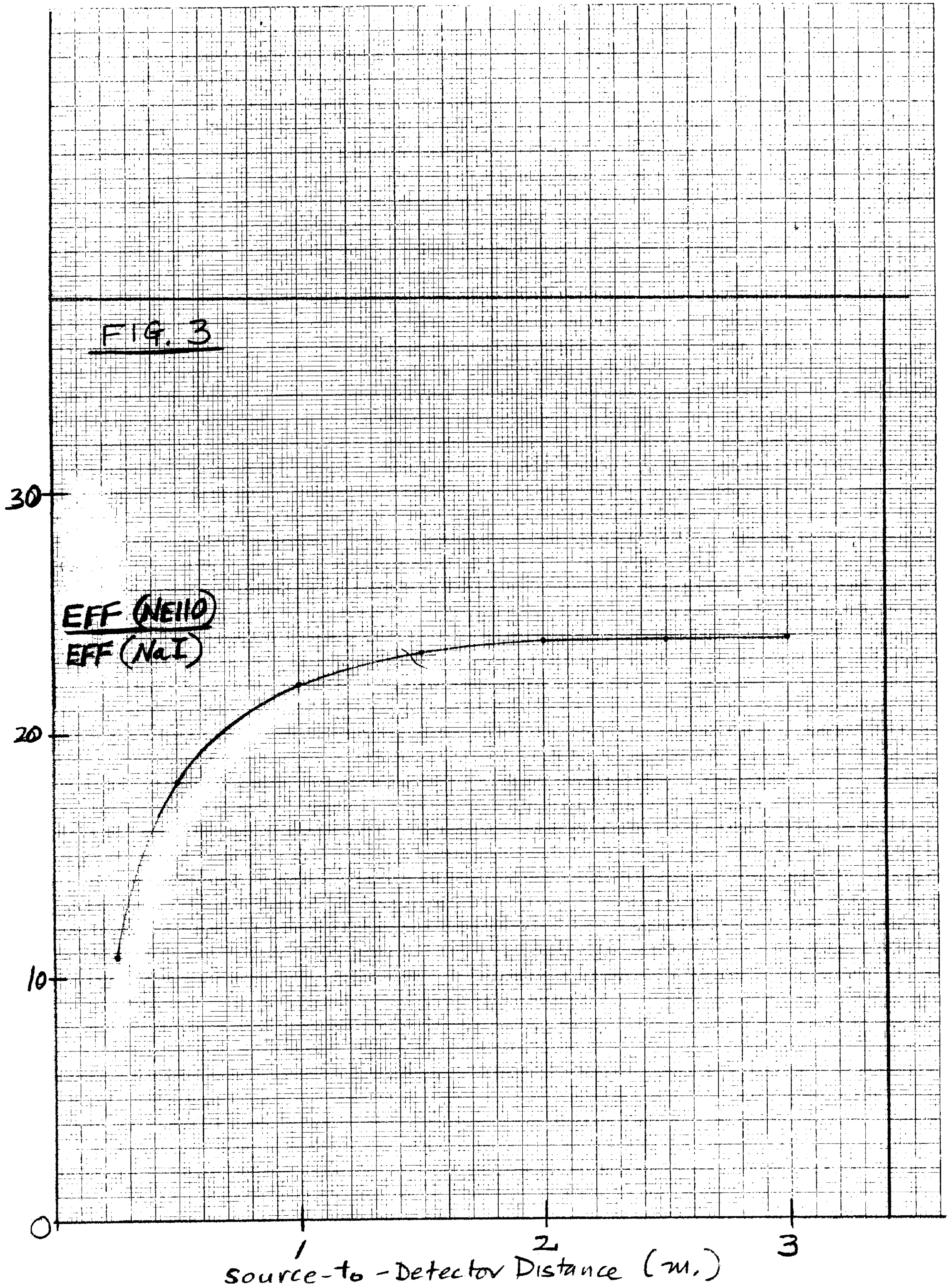


FIG. 3